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(54) A FERRULE FOR POSITIONING OPTICAL FIBRES

(71) We, THOMSON-CSF, a French Body Corporate, of 173, Boulevard Haussmann, 75008 Paris, France, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a ferrule for positioning optical fibres.

It is known that optical fibres can be used for guiding the propagation of a luminance wave. Fibres such as these consist of a thin, generally cylindrical filament of transparent material which is circular in cross-section and known as the "core" and of a cylindrical coaxial "cladding" which is also made of a transparent material having a lower refractive index than that used for the core. In the frequent case where the core and the cladding consist of two glasses having different refractive indices, the outer surface of the cladding forms the outer surface of the solid part of the fibre. More recently there have appeared types of fibres where the core is surrounded by a cladding made of a soft material both for reasons of adapting the refractive index and for reducing the fragility of the fibre. This is the case for example with fibres having a core of silica surrounded by a cladding of silicone. In their case, it is the outer surface of the core which forms the outer surface of the solid part of the fibre.

Optical fibres, whether used singly in the form of monofibres or collectively in the form of bundles, are protected by a protective "sheath" generally made of a plastics material which does not adhere to the fibre. In addition, a recent process comprises coating the cladding during extrusion of the fibre with an additional adhering layer of a soft plastics material often made of silicone, which considerably reduces the radii of curvature which the fibre is able to assume without any risk of breakage, but does not serve as a replacement for the protective sheath.

The construction of detachable connections for joining bundles of fibres of the type in question either to one another or to a radiation emitter or detector involves difficult problems attributable both to the fragility and to the fineness of the fibres. The essential component of a connector is generally the ferrule which performs a double function: firstly it protects the end of the fibre and, secondly, it provides a mechanical reference which precisely defines the position of the fibre to enable it to be optically aligned with the element to be connected. In addition, when the connector is used for a bundle of fibres, the ferrule frequently has a third function to perform, namely to gather the orifices into a compact hexagonal assemblage and to define the orientation of the hexagon thus formed to enable the two connected bundles to have the orifices of their respective fibres disposed opposite one another in order to limit the insertion losses of the connector.

The various types of ferrules for optical fibres described in the prior art are attended by the disadvantage that one and the same ferrule can only be adapted to a very narrow range of fibre diameters. In addition, the centring of the fibre for which they provide becomes very approximate when the outer wall of the fibre is soft, as is the case when the cladding is coated with a layer of soft plastics which has to be subsequently removed, for example by dissolution in a solvent. This problem of accurate centring of the fibre makes the prior art ferrules unusable when the soft outer layer forms the actual cladding of the fibre because, to deprive the core of the fibre of its cladding, even over a length of a few millimetres, would give rise to considerable optical losses.

It is also known, particularly in the machine tool industry, to use chucks with adjustable jaws for mounting rigid workpieces cylindrical in shape on the spindle of the machine. Chucks of this type, which are used for example for fixing bits of different calibre to drilling machines, are formed by an inner part comprising a set of radially displaceable jaws arranged symmetrically in relation to the axis of rotation of this inner part and by an outer part which, by moving over the inner part, causes the set of jaws to

tighten around the cylindrical workpiece to fix it in the chuck.

According to the present invention there is provided a ferrule for positioning at least one optical fibre having a core and a cladding, at least the core comprising a rigid cylindrical periphery of circular cross-section, said ferrule being characterised in that it comprises an outer body and an inner body having a common element of symmetry; said inner body comprising at least two jaws displaceable perpendicularly of said element of symmetry; each jaw having a first cylindrical contact surface; the movement of said jaws serving to bring, in use, each said contact surface into contact with a rigid periphery of a said at least one optical fibre along a common generatrix so as firmly to secure said fibre in the ferrule with the axis of said fibre coinciding with said element of symmetry; the ferrule being such that said outer body can slide without play on said inner body for controlling the displacement of said jaws; and at least part of the periphery of said outer body forms a reference surface for defining the position of the axis of said fibre relative to said ferrule.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made by way of example, to the accompanying drawings, in which:—

Figures 1a and 1b show a first example of embodiment of the ferrule according to the invention designed for fitting to a monofibre.

Figures 2a and 2b show the ferrule illustrated in Figs. 1a and 1b as it appears in accordance with the invention after fitting to a monofibre having a soft protective sheath.

Figure 3 shows a second example of embodiment of the ferrule according to the invention which is also designed for fitting to a monofibre.

Figure 4 shows a third example of embodiment of the ferrule according to the invention designed for fitting to a bundle of fibres.

Figure 5 shows a fourth example of embodiment of the ferrule according to the invention designed for a multi-fibre connector.

Figs. 1a and 1b show a first example of embodiment of the ferrule according to the invention in a version which is specifically designed for fitting to a monofibre comprises a soft outer part (cladding or protective sheath).

Fig. 1a shows the ferrule as seen from its front end where the optical fibre emerges. Fig. 1b shows the same ferrule in section along its axis of symmetry AA. In these two Figures, the ferrule is shown as it appears before fitting to a fibre.

The ferrule consists of an inner body 1 and an outer body 2, both these bodies being bodies of revolution about an axis AA. The inner body 1, which terminates in a flat front face 10, has as outer lateral surface of which the front part 11 is frustoconical and its rear part 12 cylindrical in shape. It is formed with two cylindrical bores 13 and 14, the bore 13, which opens at the rear face 10, having a larger diameter than the bare fibre, and the bore 14, opening at the rear face, having a larger diameter than the fibre provided with its protective sheath. These two bores are joined by a frustoconical part 15 which is intended to facilitate introduction of the bare fibre into the bore 13. The surface of the bore 14 is provided with indentations which may be formed very simply by a screwthread.

The front part of the inner body 1 is formed with three radial slots 161, 162 and 163 situated at angular intervals of 120° from one another and having a length at least equal to that of the frustoconical part 11. These slots thus form three jaws 111, 112 and 113 in the front part of the inner body. In the bore 13, they delimit three first contact surfaces 131, 132 and 133 and, in the front part of the bore 14, three second contact surfaces of which only the surfaces 151 and 153 are visible in Fig. 1b.

The outer body 2 is laterally limited by an outer cylindrical periphery 20 which represents the reference surface for defining the position of the axis AA intended to become the axis of the monofibre to which the ferrule is to be fitted. It comprises two bores 21 and 22 of revolution about the axis AA. The rear bore 21 has a diameter substantially equal to that of the cylindrical surface 12 so that the outer body 2 slides smoothly on the inner body 1. The diameter of the front bore 22 is comprised between the two extreme diameters of the frustoconical surface 11.

Figs. 2a and 2b show the ferrule illustrated in Figs. 1a and 1b after it has been fitted to a monofibre which has a soft cladding and which may be for example a monofibre having a core 30 of silica and cladding 31 of silicone protected by a protective sheath 32 of a plastics material.

The end of the fibre is first stripped of the protective sheath 32 and then introduced into the bore 14 until the end of the protective sheath 32 comes into contact with the frustoconical part 15. The core and the cladding pass through the bore 13, the bare end of the fibre projecting beyond the front face 10.

Two simultaneous but oppositely directed pressures are then applied respectively to the rear face of the outer body 2 and to the front face 10 of the inner body. The cylindrical part 22, which bears on the frustoconical surface 11, deforms it and produces a symmetrical radial displacement of the three jaws 111, 112 and 113 towards the axis AA until the three first contact surfaces 131, 132 and 133 are in contact with the core 30 of the monofibre which forms the solid part thereof.

Since the diameter of the bore 13 is larger than the diameter of the core of the fibre, the first contact surfaces come into contact with the monofibre solely along three generatrices. In order to prevent the core from being deformed by an excessive pressure applied to the ferrule, this pressure may be applied to a dynamometric clamp. As shown in Fig. 2a, the soft silicone cladding 31 moves into the space between the core and the contact surfaces and flows back inside the slots 161, 162 and 163. The core of the monofibre thus remains surrounded by its cladding, except along the three generatrices where it is in direct contact with the material of the ferrule. Accordingly, the optical losses occurring over these portions of the core surface, which have been deprived of the cladding, are considerably reduced by comparison with the prior art. In addition, since the inner body 1 slides without any play in the outer body 2 and since the radial displacement of the jaws is perfectly symmetrical in relation to the axis of the inner body 1, the axis of the fibre, providing its core has a perfectly circular cross-section, coincides exactly with the axis of the reference surface 20 which forms the periphery of the outer body 2.

At the same time, the radial displacement of the three jaws enables the screwthread formed on the second contact surfaces to dig into the protective sheath 32.

Since the core of the fibre and the protective sheath are thus firmly secured in the ferrule by the first and second contact surfaces, respectively, there is no need for the fibre and its protective sheath to be subsequently bonded. The ferrule may thus be withdrawn from the fibre without the least difficulty.

In the example of embodiment illustrated in Figs. 1 and 2, the half-angle at the top of the frustoconical surface 11 amounts to between 6° and 10° before deformation, decreasing to values of from 1 to 6° after deformation. Under these conditions, the frictional forces between the surfaces 11 and 12 are sufficient to hold the outer body in position on the inner body after the fibre has been fixed in the ferrule.

Fig. 3 is an axial section through a second example of embodiment of the ferrule according to the invention which is very similar in its principle to the ferrule shown in Figs. 1a and 1b but in which the radial displacement of the three jaws is obtained by screwing the outer body 2 onto the inner body 1. As in the example of embodiment shown in Figs. 1a and 1b, the inner body 1 is externally limited towards the front by a frustoconical surface 11 and towards the rear by a cylindrical surface and comprises three radial slots at 120° from one another, of which only the slot 161 is visible in Fig. 3. These slots delimit the three jaws. In the embodiment shown in Fig. 3, in contrast to the embodiment shown in Figs. 1a and 1b, the frustoconical surface 11 has sections decreasing in diameter from the rear towards the front of the inner body.

In this second example of embodiment, the cylindrical periphery of revolution 20 of axis AA of the outer body 2 again forms the reference surface of the ferrule. The rear bore 21, also of axis AA, slides smoothly on the surface 12. The surfaces 12 and 21 are formed with two screwthreads 121 and 211 which enable the outer body to be screwed onto the inner body, bringing the front bore 22 to bear on the frustoconical surface 11 to cause the radial displacement of the three jaws.

A third example of embodiment of the ferrule according to the invention, designed for the compact assemblage of the orifices of the fibres of a bundle, is shown in Fig. 4 in which the ferrule is seen from its face and which enables the modifications made to the inner body 1 of the ferrule shown in Figs. 1a and 1b for obtaining this result to be understood. To enable this version of the invention to be better understood, the ferrule has been shown as it appears after fitting a bundle comprising nineteen fibres 300 surrounded by a rigid cladding and, in this connection, may advantageously be compared with Fig. 2a. The bore 130 of uniform hexagonal cross-section, which opens at the front face of the inner body and which is centred on the axis of the bundle, replaces the circular bore shown in Figs. 1a and 1b, the three radial slots 161, 162 and 163 having been replaced by six radial slots 164 to 169 disposed at regular angular intervals of 60° from one another, each of them opening at one edge of the hexagonal bore 130 and delimiting six jaws 114 to 119 in the front part of the inner body. The width of the slots in the absence of compression by the outer body is smaller than the diameter of the fibres 300 forming the bundle so that, when the bundle is inserted into the ferrule, the fibres are unable to engage in the slots. The longitudinal displacement of the outer body relative to the inner body, which causes the radial displacement of the jaws, reduces the apothem of the regular hexagonal prismatic surface described by the front contact surfaces of the jaws, also called the first contact surfaces, 134 to 139, and forces the ends of the fibres of the bundle to fall into a compact hexagonal arrangement centred on the axis of revolution of the reference surface 20 formed by the periphery of the outer body. A flat portion 200 formed on a part of this reference surface parallel to one of the facets of the hexagonal bore 130 enables the orientation of the hexagonal arrangement of the bundle to be based on the ferrule. As in the ferrule shown in Figs. 1a and 1b, the rear

part of each jaw comprises a second contact surface, not shown in Fig. 3, which is formed by part of a cylindrical surface and which is provided with indentations which, by digging into the sheath of the bundle, keep it fixed in the ferrule.

The six-jaw arrangement shown in Fig. 4 may of course also be adapted to the ferrule shown in Fig. 3 where the radial displacement of the jaws is obtained by screwing the outer body onto the inner body.

Fig. 5 illustrates a fourth example of the ferrule according to the invention designed for a multifibre connector intended for a cable comprising several fibres which are each equipped with their own protective sheath and which may comprise a soft cladding. This bird's-eye view has been sectioned to make the construction of the inner part of the ferrule easier to understand.

As in the preceding examples of embodiment, the ferrule shown in Fig. 5 comprises an inner body 1 and an outer body 2. The ferrule as a whole is symmetrical in relation to a plane in which the axes of the fibres are situated.

The periphery of the outer body 2 is in the form of a rectangular parallelepiped of which the four flat lateral surfaces form the reference surface enabling the position of the axes of the various fibres to be defined. Among the faces forming this reference surface, only the face 201 is visible in Fig. 5.

The rear part of the inner body 1 is also parallelepipedic and, with its four flat lateral surfaces, slides smoothly on four inner flat faces, such as the face 121, of the rear part of the outer body 2. The front part of this same inner body is trapezoidal in cross-section. The inner body comprises as many bores as there are fibres in the bundle. Each bore comprises a front cylindrical part 13 slightly larger in diameter than the bare fibre and a rear part 14 which is also cylindrical and which is larger in diameter than the sheath of the fibre, these two parts being joined by a frustoconical part 15.

The front part of the inner body 1 is formed with slots which, starting from the front face 10, extend over the entire part of trapezoidal cross-section and over the front portion of the parallelepipedic part. One of these slots is formed in the plane of symmetry and extends over the entire width of the front face 10. The other slots, extending perpendicularly to the preceding slot over the entire height of this same front surface, are equidistant from one another. Together, these slots form in the front part of the inner body as may pairs of jaws 11a, 11b as there are fibres to be accommodated in the ferrule. Each jaw comprises two contact surfaces 13a, 14a, of which the first, situated at the front, is intended to clamp the fibre and the second, situated at the rear, to hold the protective sheath when the jaws are tightened. The jaws are tightened by forcing the inner body into the outer body, for example by means of a dynamometric clamp. By sliding on the outer surface of the jaws, the two edges, of which only the edge 23 is visible in the Figure, apply to these edges simultaneous pressures which cause the two jaws of one and the same pair to move towards one another. In order to compensate the slight differences in diameter which may exist between the fibres of one and the same cable or between the cores of these fibres when they comprise a soft cladding, the outer surfaces of the jaws may be lined with a layer 110 of elastic material, for example rubber.

Thus there may be provided a ferrule having an element of symmetry (an axis or a plane) with which coincide the axis of the fibre, the axis of the bundle of fibres or the axes of the fibres of a cable. It comprises an outer body of which the periphery serves as positioning reference for said axis or axes and which slides on an inner body comprising jaws displaceable under the action of the outer body in a direction perpendicular to the element of symmetry; the contact surfaces of these jaws are in contact with the fibre(s) along a single generatrix of the rigid part of the fibre. The ferrule may be used with fibres having a soft protective sheath or to enable a bundle of fibres to be assembled into a compact arrangement. Such a ferrule is useful in particular in optical telecommunications.

WHAT WE CLAIM IS:—

1. A ferrule for positioning at least one optical fibre having a core and a cladding, at least the core comprising a rigid cylindrical periphery of circular cross-section, said ferrule being characterised in that it comprises an outer body and an inner body having a common element of symmetry;
—said inner body comprising at least two jaws displaceable perpendicularly of said element of symmetry; each jaw having a first cylindrical contact surface; the movement of said jaws serving to bring, in use, each said contact surface into contact with a rigid periphery of a said at least one optical fibre along a common generatrix so as firmly to secure said fibre in the ferrule with the axis of said fibre coinciding with said element of symmetry;
—the ferrule being such that said outer body can slide without play on said inner body for controlling the displacement of said jaws; and at least part of the periphery of said outer body forms a reference surface for defining the position of the axis of said fibre relative to said ferrule.

2. A ferrule as claimed in Claim 1, characterised in that, when said contact surfaces are in contact with said rigid periph-

ery of an optical fibre, the opposite lateral surfaces of two consecutive jaws remain out of contact with one another.

3. A ferrule as claimed in Claim 1, characterised in that, where said fibre additionally comprises a protective sheath, each said jaw additionally comprises a second cylindrical contact surface for bearing on said sheath and securing it firmly in said ferrule.

4. A ferrule as claimed in Claim 3, characterised in that, where said element of symmetry is an axis of symmetry, said jaws are n in number, n being an integer at least equal to 2, and are arranged in a symmetry of order n in relation to said axis; said reference surface being a cylinder of revolution.

5. A ferrule as claimed in Claim 4, characterised in that:

—said inner body is externally limited by two lateral surfaces of revolution, the rear surface being cylindrical and the front surface frustoconical, and comprises a rear cylindrical bore of revolution for receiving the fibre provided with its protective sheath and a front cylindrical bore for receiving the bare fibre; n radial slots being formed in the front face of said inner body in a symmetry of order n, extending from said lateral faces to said bores over a part of said rear bore and delimiting said jaws; each surface element of said front and rear bores comprised between two successive slots respectively forming said first and second contact surfaces of said jaws;

—said outer body being drilled end to end, for receiving said inner body, with two cylindrical cavities of revolution, the first having the same diameter as said cylindrical lateral surface and the second having a diameter comprised between the two extreme diameters of said frustoconical lateral surface.

6. A ferrule as claimed in Claim 5, characterised in that said cylindrical lateral surface and said cylindrical cavity each comprise a screwthread over at least part of their length, said screwthread enabling said outer body to be screwed onto said inner body.

7. A ferrule as claimed in Claim 4, characterised in that, where n is equal to 6, said first contact surfaces are flat.

8. A ferrule as claimed in Claim 3, characterised in that, where said element of symmetry is a plane of symmetry, it comprises *p* pairs of jaws, each pair bearing on one said fibre to orient its axis in said plane of symmetry; said reference surface being formed by four orthogonal planes, of which two are parallel to said plane of symmetry; said inner part sliding in said outer part along four orthogonal planes parallel to the planes forming said periphery; the front of said inner part being formed with a slot situated in the plane of symmetry and with p-1 slots situated at regular intervals perpendicularly of said plane of symmetry, said slots delimiting the p pairs of jaws in the front of the inner part; said inner part comprising p bores, each bore being a bore of revolution about an axis situated in said plane of symmetry; the rear part of said bore having a larger diameter than said fibres provided with their sheaths and the front part having a larger diameter than said bare fibres; said front parts forming said first contact surfaces and the front part of said rear parts forming said second contact surfaces.

9. A ferrule substantially as hereinbefore described with reference to Figures 1*a*, 1*b*, 2*a* and 2*b*, or with reference to Figure 3, 4 or 5 of the accompanying drawings.

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1598598 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

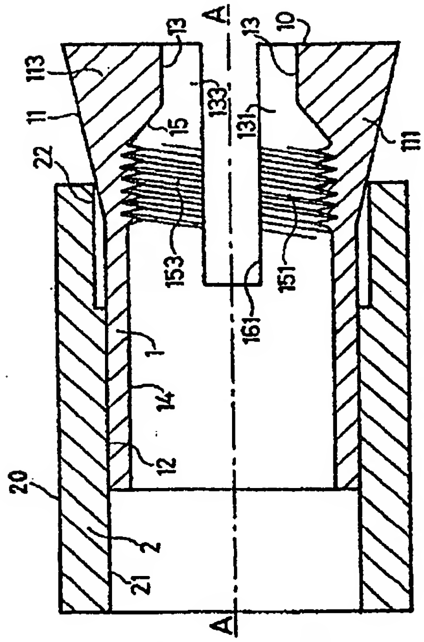


FIG. 1b

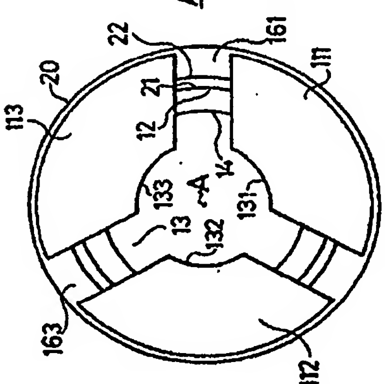
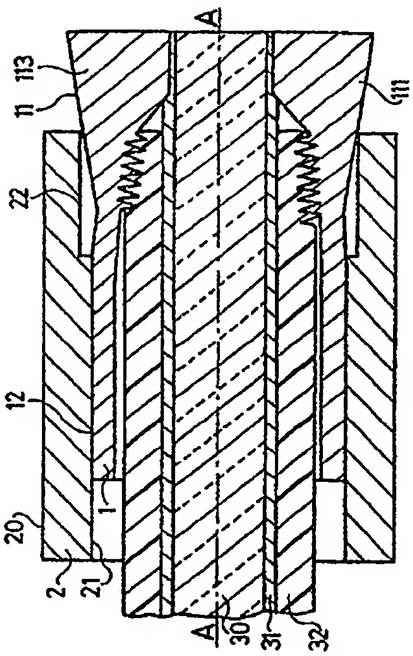


FIG. 1a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12
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Fig. 2b

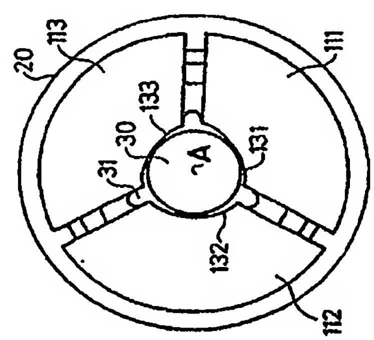
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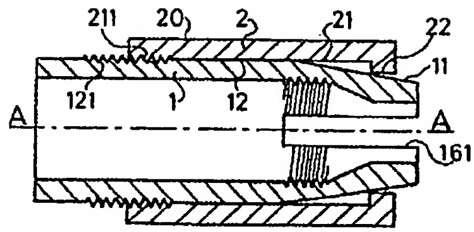
Fig. 2a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121
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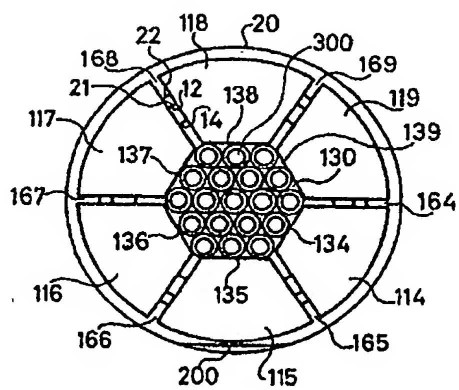
161

FIG. 3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169
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FIG. 4

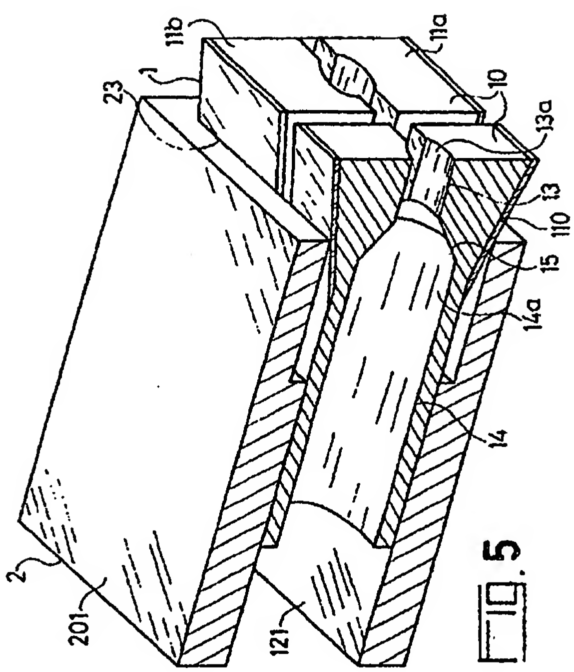

FIG. 5